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# Activities and Capabilities in Ultrafast and Integrated Photonics

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# MBE of Complex Materials

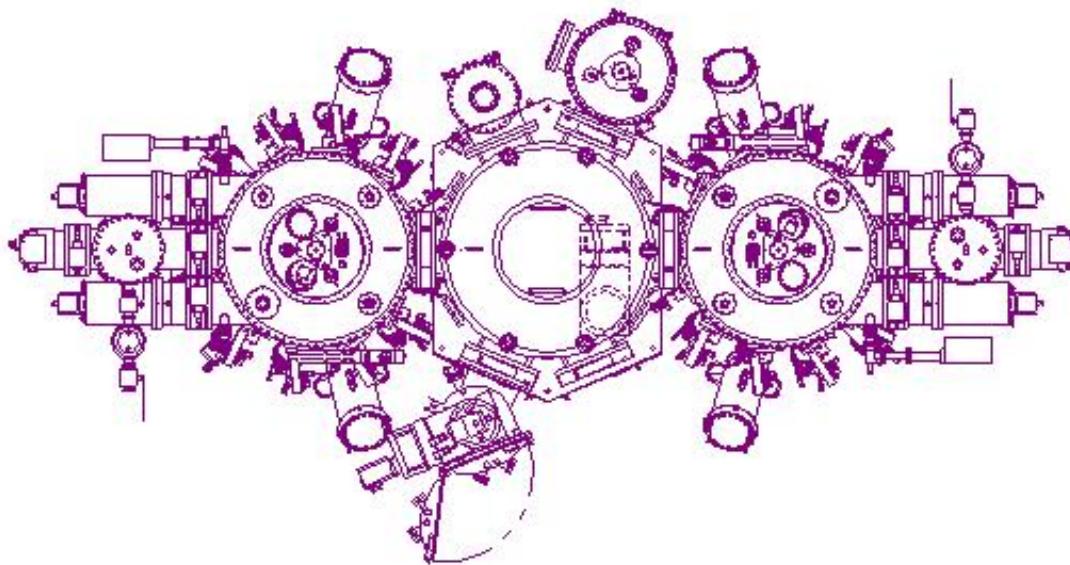
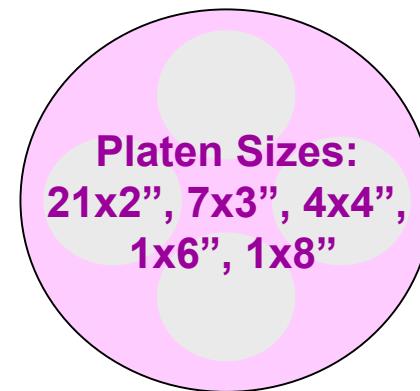
## (As,P)-based Reactor

Sources: 2-Ga, 2-In, Al

Crackers: As, P

Dopants: Si, Be, C

Gas Sources: H<sub>2</sub>, N<sub>2</sub>



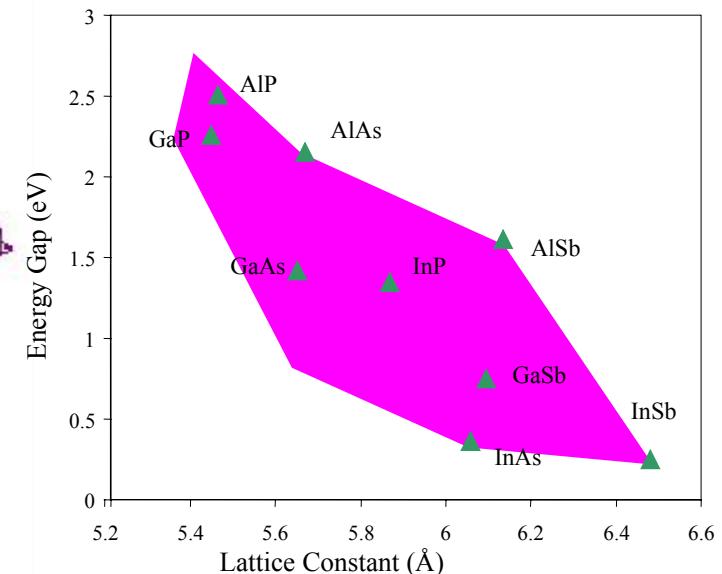
## Sb-based Reactor

Sources: 2-Ga, 2-In, Al

Crackers: As, P, Sb

Dopants: Si, Be, C

Gas Sources: H<sub>2</sub>, N<sub>2</sub>

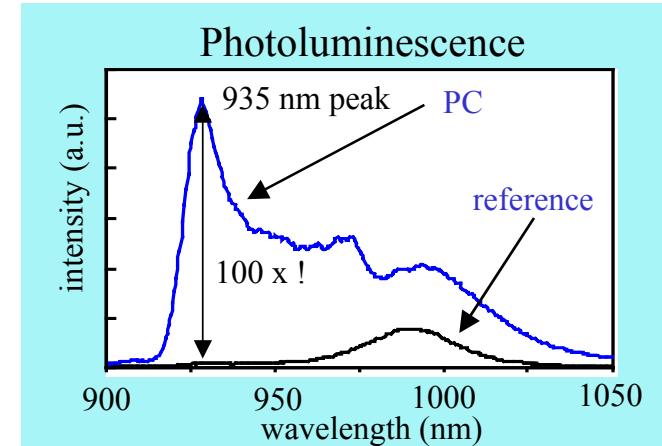
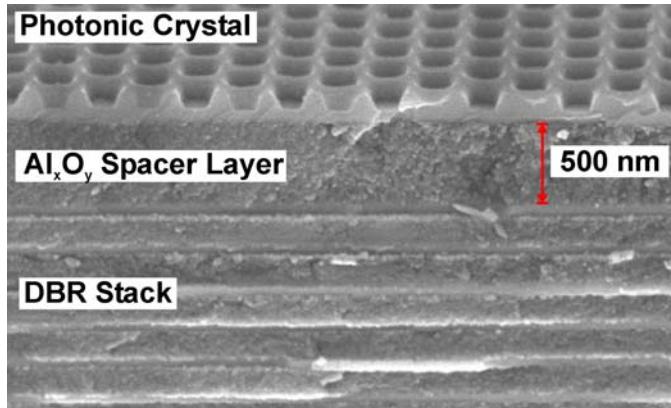


Kolodziejksi Group

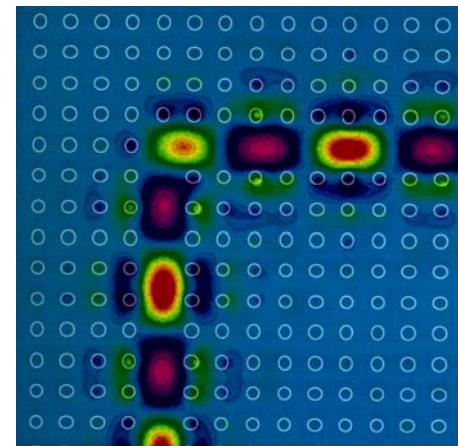
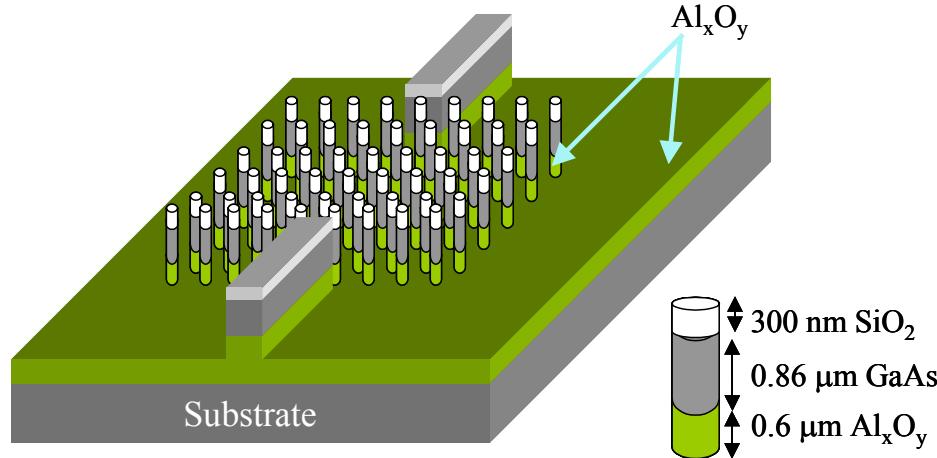
MIT Research Laboratory of Electronics

# 2-D Photonic Bandgap Structures

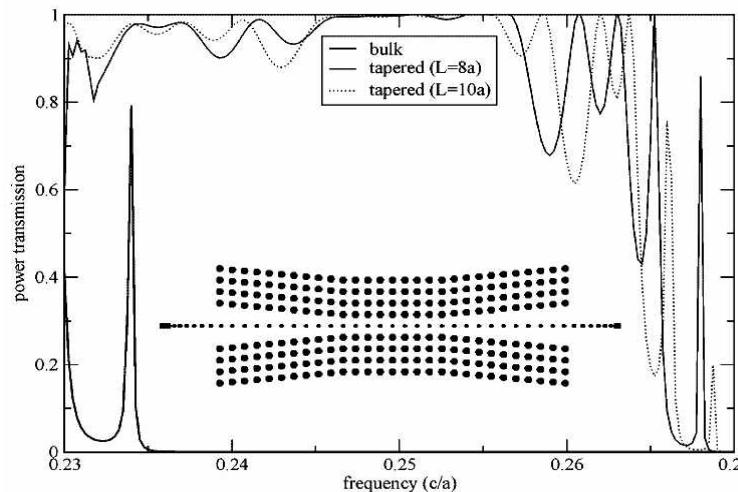
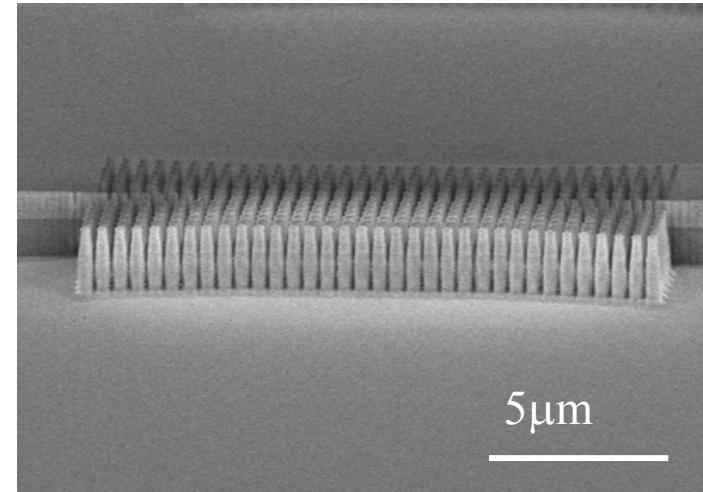
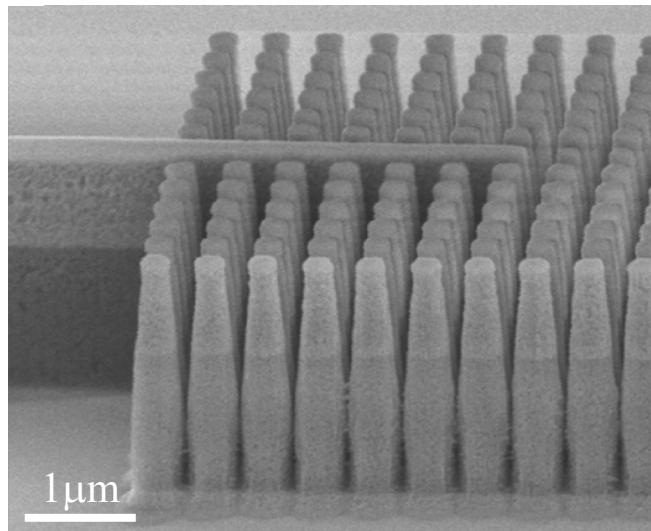
Enhanced input / output coupling



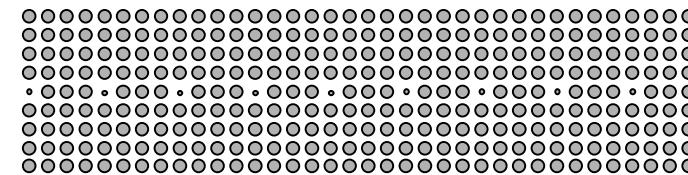
Photonic crystal waveguiding and coupling



# 2D Photonic Crystal Waveguiding



Tapered coupling to PBG structures



Coupled-cavity slow wave structure

Kolodziejski, Joannopoulos, Ippen



# Expertise in Joannopoulos Group

## ***Unique Numerical capabilities (all developed in-house) :***

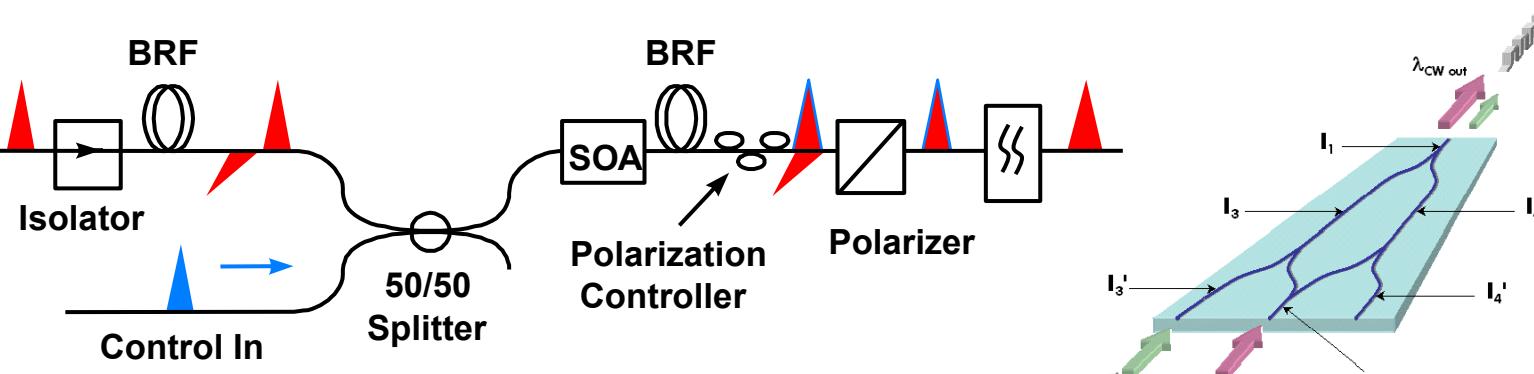
- 3D Time-domain code (with perfectly matched layers boundary condition):
  - simulates Maxwell's vector equations **exactly**
  - includes full instantaneous optical non-linearity
  - includes material dispersion
  - parallelized, so it can run on any number of processors
- 3D Frequency-domain code:
  - computes eigenmodes of Maxwell's vector equation in the frequency domain
  - provides any arbitrary integral of eigenfields for studies of non-linear effects with great accuracy

## ***Theoretical expertise:***

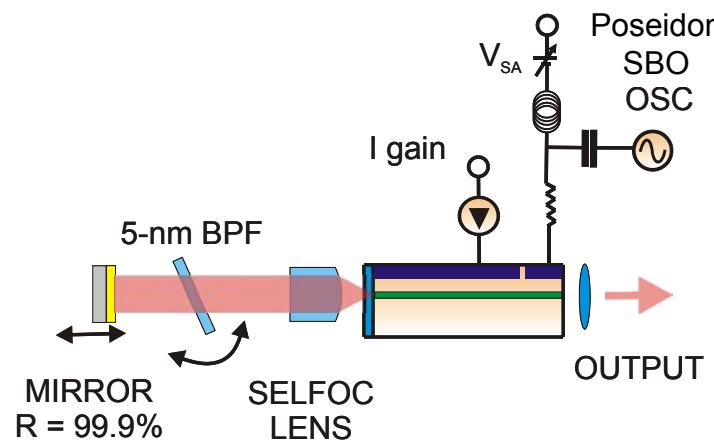
- Numerous studies of *nonlinear switching* in photonic crystal systems :
  - devices designed with bistability threshold at mW peak powers,  $< \lambda^3$  in size, compatible with  $>10\text{Gbit/sec}$  signals (in e.g. GaAs, or  $\text{As}_2\text{Se}_3$ )
  - other applications such as all-optical logical gating, all-optical pulse reshaping & regeneration and wavelength conversion have been computationally demonstrated.
- Devices using *slow-light* in photonic crystals have also been simulated
  - slowing down light enables savings of a factor  $>(v_G/c)^2$ , in either device length or power
  - using slow light with Mach-Zehnder geometry all-optical switching can be performed in a device a few hundred microns long with a few tens of mW and  $>40\text{Gbit/sec}$  signals
- Inputs and outputs are single-mode waveguides and are designed for minimum reflection/loss



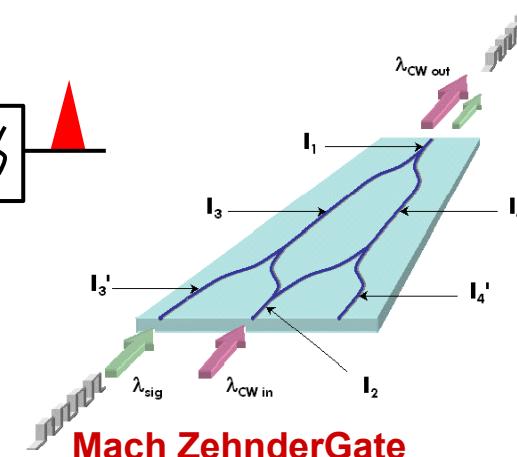
# SOA-Based All-Optical Gates and Short-Pulse Diode Lasers



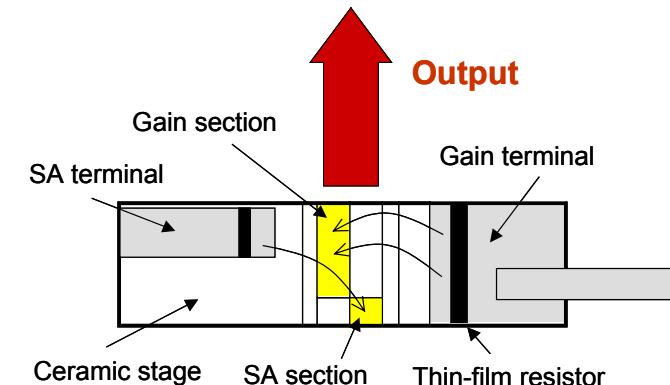
UNI Gate



10 GHz Active-Passive MLLD



Mach ZehnderGate



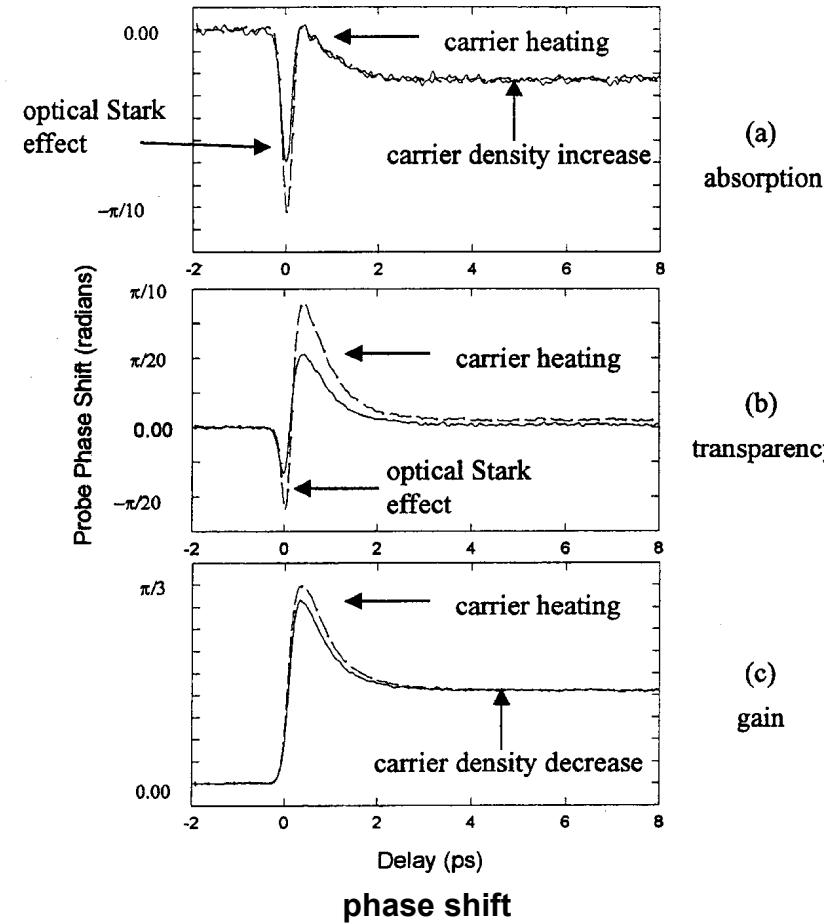
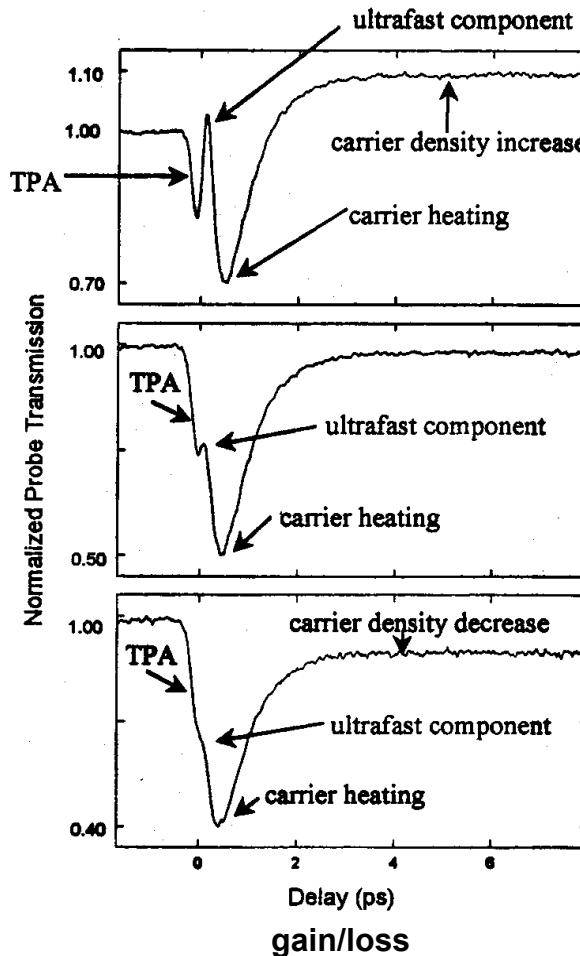
45 GHz Passive MLLD

Ippen & Lincoln Lab

MIT Research Laboratory of Electronics

# Gain and Index Dynamics in SOA's

- InGaAsP
- fs pump-probe



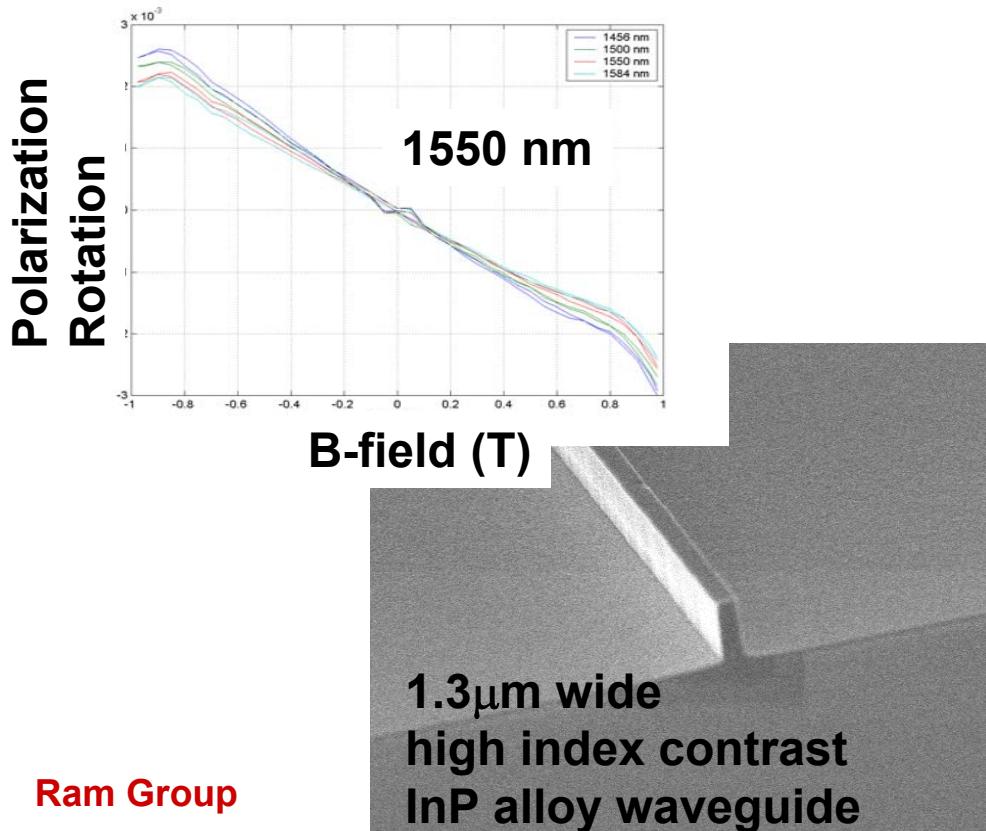
Ippen group

# Optical Isolators and Ultrafast Absorbers for Integration

InP waveguide isolators

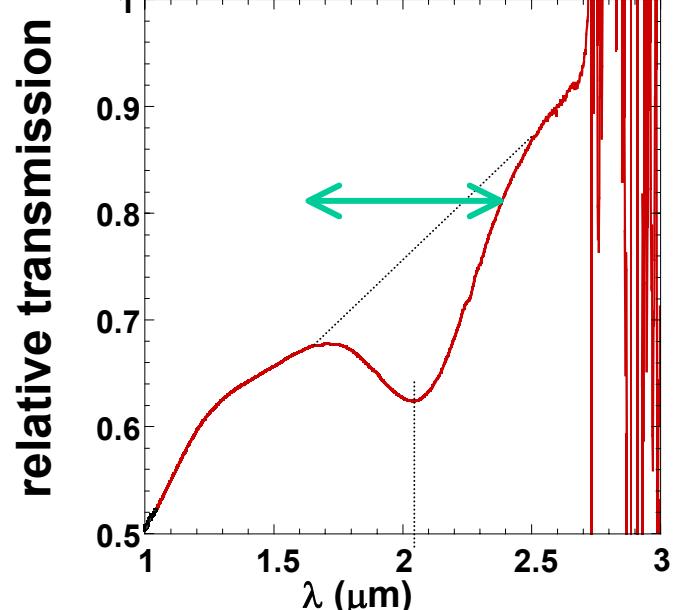
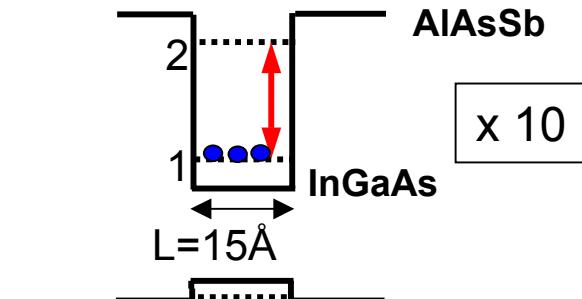
Measured Verdet /  $\alpha = 500$  at 1550 nm

 >90% transmission with 45° rotation



Deep intersubband absorber on InP

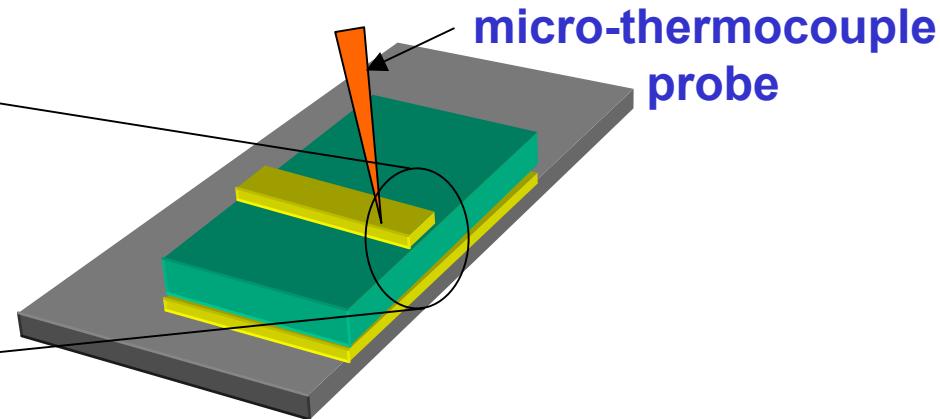
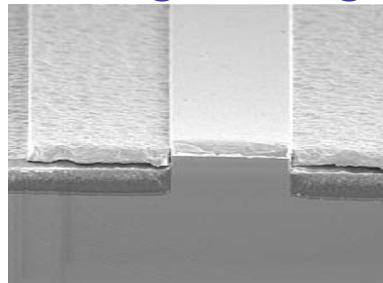
ps recovery without bias & ASE



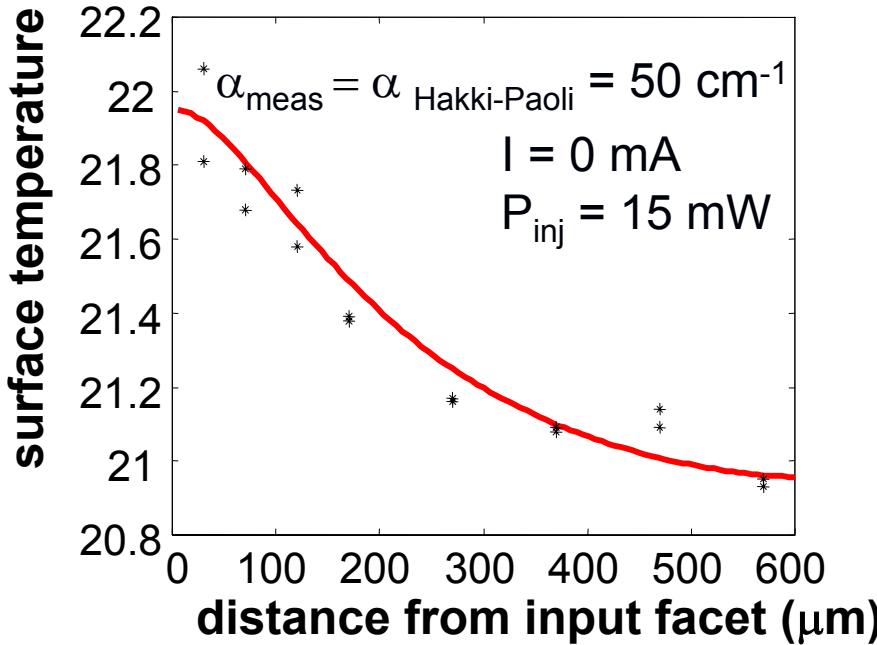


# Measurements of Gain and Optical Power via Surface Probing

InP ridge waveguide



Optical gain/loss measurements



Wafer-scale testing of edge emit. lasers

